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Tourism, Environment and Energy: An Analysis for China¹

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Tourism, Environment and Energy: An Analysis for China

Abstract: International tourism as a cause of global warming is a controversial and topical issue. Here, we use the novel Morlet wavelet time-frequency approach to gain insight into the dynamic nexus between tourism, renewable energy consumption, energy consumption and carbon dioxide emissions for China using annual data over the period 1974-2016. The techniques we use include continuous wavelet power spectrum, the wavelet coherency, and the partial and the multiple wavelet coherence for time-frequency decomposition that can capture local oscillatory components in time series. Our findings support the hypothesis that tourism can cause increased energy consumption and carbon dioxide emissions in China, which challenges the sustainable tourism development goal. However, on the positive side, the relationship between tourism and renewable energy consumption is shown to facilitate reduced environmental degradation in the medium-long run.

Keywords: Energy consumption; renewable energy; CO₂ emission; tourism; partial and multiple wavelet coherence; country study

JEL: Q32; Q35; Q53; Z30; Z32

1. Introduction

On one hand, international tourism is seen as an important engine for generating growth and employment in developing countries. On the other hand, it is seen as a contributor to global warming particularly with regard to the carbon dioxide (CO₂) emissions from aircraft, cruise ships and accommodation construction. Tourism is estimated to account for 5% of global carbon emissions (Solarin, 2014; and Othman, Mohamed, & Aziz, 2012). We need to be careful about concluding that a simple trade off exists here. During the earlier stages of economic growth, nations rely more on fossil fuel-based energy solutions, as this energy solution is cost effective. However, the fossil fuel-driven growth trajectory results in ambient air pollution through greenhouse gas emissions, of which CO₂ holds a major share. Gradual rise in this emission level poses a threat before the hygienic state of the labour force, and thereby, jeopardizing the growth trajectory. In order to sustain the economic growth, the nations need to retain the environmental quality, and in pursuit of retaining environmental quality, policymakers start investing in renewable energy projects. Hence, the objective of sustainable economic growth puts a country in a strong position to invest in renewable energy projects. To gain insights into this complex issue, our paper, using China as a case study, explores the dynamic association between the following variables: tourism, renewable energy consumption, fossil fuel energy consumption, and CO₂ emissions. With China, its vast tourism industry and substantial effect on global warming, makes it an obvious choice. Since the relationship between these variables is complex and ambiguous, we take the Morlet wavelet time-frequency approach. This allows us to look for evidence of a causal relationship between tourism demand and CO₂ emissions, and, to explore the mitigating effects of renewable energy.

The Chinese tourist industry has rapidly expanded since the economic reform in the late seventies. According to the World Travel and Tourism Council Report (WTTC, 2018), China ranks second after the United States in terms of the size of travel and tourism, as a contributor to GDP. During 2017, this sector contributed US\$402.3 billion directly to Chinese GDP, it generated 28,250,000 jobs and it is predicted that the employment in the tourism sector will grow by 1.5% in 2018, with international tourist arrivals expected to be 63,539,000. The growth prospects for the tourism industry are very strong with a forecasted increase of 1.8% per annum in the upcoming ten years (WTTC, 2018). With the increase in China's tourism and the use of energy by this sector, its impact on the environment is a matter for concern. Shuxin, Genxu, & Yiping (2016) show that tourism-induced energy consumption in China has increased from 178.21 PJ to 565.82 PJ between 1994-2013, and during the same period, the CO₂ emissions from tourism-induced transport have increased from 14.96 Mt to 47.94 Mt. This increase has been attributed to the rise in per-person distance for every trip, along with the number of trips. Using carbon-input-output table, Tang and Ge (2018) show that the carbon footprint of tourism in China is more than 20 per cent of the total CO₂ emissions.² Using the similar methodological approach, Li, Li, Tang, & Wang (2019) have estimated the nearly 39 per cent of the CO₂ emissions from transport sector is caused by tourism-related activities. In 2012, 25.70 per cent of the total CO₂ emissions in Beijing were caused by tourism-related activities (Beijing Municipal Bureau of Statistics, 2014). Wu and Shi (2011) state that energy use and its impact on the environment increase synchronously with China's growing tourism. To accomplish the strategic objective of environmental sustainability along with tourism development, it is important to follow the strategic paths which respect the environment as well as ensure optimal economic

² We have considered the estimations of different researchers, as China Energy Statistics Yearbook does not contain any particular information on tourism-induced energy use (see Tang et al., 2014; Chen, Thapa, & Yan, 2018).

benefits from tourism. Gössling, Scott, and Hall (2013) argue that all sectors, including tourism, need strong mitigation for the associated greenhouse gas emissions (GHG) so as to achieve the objective of reducing global emissions by 80% from the current level by 2050.

The search for cheap and secure energy sources by the developed and energy dependent countries has raised the demand for alternative energy sources (alternatives to fossil fuels) for dealing with global warming and GHG emissions. The role of renewable energy in sustainable energy supply and reductions of carbon emissions has been widely acknowledged in the last ten years (Ocal & Aslan, 2013). The threat of extinction of fossil fuels and increasing concerns regarding CO₂ emissions and global warming have helped in the emergence of renewable energy sources. Renewable energy is the fastest growing source of energy in the world, its consumption has been increasing at an average of 2.3% per year since 2015 and this is expected to continue until 2040 (EIA, 2017). This increase in consumption of renewable energy sources includes wind energy, biomass energy, hydropower energy, waste energy and geo-thermal energy. China has started adopting the strategy of using renewable energy for dealing with issues of climate change and sustainable energy supply and is becoming a leading investor in this sector.

This study examines the dynamic connection between tourism, renewable and fossil fuel energy consumption, and CO₂ emanations for ascertaining sustainable tourism development in China. Over the years, China is gradually turning out to be a popular tourism destination in the globe, and in order to facilitate the tourism in China, policymakers are relying on the transport sector. Now, this sector is largely dependent on the fossil fuel-based energy solutions, and the environmental degradation caused by the tourism activities is largely caused by the transport sector only. In terms of CO₂ emissions from tourism, China stands second in the world (Lenzen et al., 2018). In a recent study carried out on Yangtze River Delta, it has been seen that the

tourism-related energy consumption has increased by 3.57 times and tourism-borne CO₂ emissions have increased by 3.19 times between 2001 and 2015 (Chen, Thapa, & Yan, 2018). Moreover, emergence of ecotourism in China, the country is experiencing faster depletion of natural resources, and this situation can be attributed to the existing transportation architecture (UNEP, 2008). These concerns gradually diminished the acceptability of fossil fuel based energy solutions and increased the demand of renewable energy solutions in the tourism sector in China. Owing to this scenario, 13th Five-Year Plan for Tourism Development of Beijing is focused at promoting clean energy-driven vehicles for the purpose of tourism (UNWTO, 2018). Because of these developments in China, this study aims to assess the association between tourism, renewable and fossil fuel energy consumption, and CO₂ emanations in China.

Following Aguiar-Conraria, Azevedo, and Soares (2008) and Aguiar-Conraria, and Soares (2011), we investigate the dynamic associations by applying innovative continuous wavelet power spectrum and wavelet coherence techniques, which decompose time-frequencies of the variables being studied. Also, using the wavelet tools, we identify the changes both over time and differences across frequencies in tourism and energy variables within a unified framework. The wavelet power spectrum, in particular, can be easily adapted to consider the time-varying features at each periodic component that has not been apprehended so far. Besides, we employ partial and multiple wavelet coherence techniques to assess the association among the model parameters. These techniques assess the wavelet coherence across diverse temporal domains subsequent to adjusting conjoint factors and explanatory power of model parameters (Ng & Chan, 2012). Owing to the convolution of the association, partial and multiple wavelet coherence techniques can advocate comprehensive conclusions concerning the associations in the frequency domain.

Our study contributes to the literature of tourism economics through several dimensions: (a) considering the sustainable tourism in China, this study bring together the perspective of sustainable energy and environmental policies, which has hardly been considered in the literature, (b) the association between tourism, renewable and fossil fuel energy consumption, and CO₂ emission has been analyzed in the frequency domain by localized oscillatory components in the time-frequency area (Aguiar-Conraria et al., 2008), and thereby, overriding the shortcomings of the traditional time series analysis, (c) the choice of Morlet wavelet enables us to harvest “information on the amplitude and phase, both essential to study synchronism between different time-series” (Aguiar-Conraria & Soares, p. 648, 2011), and (d) by means of the lead-lag movement divulged through wavelet analysis, we are able to analyse the trajectory of the associative movement among the model parameters.

The remainder of the paper is set out as follows. The next section elaborates on the existing literature. The third section explains the model framework and data. The fourth section discusses the results and findings. The final section concludes with a discussion of policy implications.

2. Literature Review

The existing empirical literature on CO₂ emission and economic development finds an association between CO₂ emission, economic growth and energy consumption (Aslanidis & Iranzo, 2009; Apergis & Payne, 2010; Ozturk, 2010; Shahbaz & Sinha, 2019). On the other hand, world-wide tourism has enjoyed an above-average growth rate, at around 4% per year, for the last eight straight years (UNWTO, 2017). Obviously, it has the potential to substantially increase energy consumption and CO₂ emission. However, the actual effect upon global warming

is going to be critically dependent upon the use of renewable energy; hence this literature is also discussed below.

2.1. Carbon dioxide emissions and non-renewable energy consumption

Non-renewable energy consumption is considered one of the most vital determinants of CO₂ emissions. Several studies investigate the relationship between non-renewable energy consumption and CO₂ emissions. For instance, Say and Yucel (2006) find a significantly positive relationship between energy consumption and CO₂ emissions in Turkey. Jalil and Mahmoud (2009) examine the relationship between energy consumption, income, trade openness and CO₂ emissions in China during 1975-2005 and find a similar story. Various studies confirm this positive relationship between energy consumption and CO₂ emissions such as Apergis and Payne (2009), Niu, Ding, Niu, Li, and Luo (2011), Jayanthakumaran, Verma, and Y. Liu (2012), Shahbaz, Khraief, Uddin, and Ozturk (2014), Tang and Tan (2015), Ibrahiem (2016), and Riti, Song, Shu and Kamah (2017).

Several studies that investigate the causal relationship between energy consumption and CO₂ emissions find inconclusive results. Some finds a bidirectional causal relationship such as Apergis and Payne (2009), Alam, Begum, Buysse, Rahman, and Huylensbroeck et al. (2011), and Shahbaz, Farhani, and Ozturk (2015). In contrast, other studies find a unidirectional causal relationship from energy consumption to CO₂ emissions such as Zeshan and Ahmed (2013), Alshehry and Belloumi (2015), and Shahzad, Kumar, Zakaria and Hurr (2017). In addition, a unidirectional causal relationship from CO₂ emissions to energy consumption is found in other studies as such Lean and Smyth (2010).

2.2. Carbon dioxide emissions and renewable energy consumption

Some of the literature, for example Sebri and Ben-Salha (2014) focus on renewable energy consumption as an important determinant that can mitigate greenhouse gas emissions and CO₂ emissions in particular. Most of these studies examine the relationship between CO₂ emissions and renewable energy consumption and conclude that a negative relationship holds, i.e. an increase in renewable energy consumption reduces CO₂ emissions; notably: Chiu and Chang (2009), Bilgili, Koçak, and Bulut (2016), Zoundi (2017), and Álvarez-Herranz, Balsalobre-Lorente, Cantos, and Shahbaz (2017). However, some of this literature finds mixed results such as Sebri and Ben-Salha (2014). Some other studies examine the relationship between renewable energy consumption, non-renewable energy consumption and CO₂ emissions. Al-Mulali Fereidouni, and Mohammed (2015) examines the relationships between renewable electricity consumption, non-renewable electricity consumption, capital, labour, exports, imports and CO₂ emissions in Vietnam for the period 1981-2011 and finds that non-renewable electricity consumption contributes to CO₂ emissions while renewable electricity consumption has no effect on it. Ben-Jebli and Ben-Youssef (2015) in Tunisia find a positive relationship between non-renewable energy consumption and CO₂ emissions and a negative relationship between renewable energy consumption and CO₂ emissions. Dogan and Seker (2016) investigate the relationship between renewable energy consumption, non-renewable energy consumption, trade openness, real income and CO₂ emissions for European Union Nations over the period 1980-2012 and they conclude that there exists a negative relationship between CO₂ emissions and renewable energy consumption, and there exists a positive relationship between non-renewable energy consumption and CO₂ emissions. Bento and Moutinho (2016) find a negative relationship between renewable electricity consumption and CO₂ emissions in Italy. Dogan and Ozturk (2017) examine the relationship between renewable energy consumption, non-renewable energy

consumption, real income and CO₂ emissions for the United States of America and they confirm the existence of a positive relationship between non-renewable energy consumption and CO₂ emissions and a negative relationship between renewable energy consumption and CO₂ emissions. Similar results are reached by Sinha, Shahbaz, and Balsalobre (2017) for N-11 countries.

2.3. Carbon dioxide emissions, renewable/non-renewable energy consumption and tourism development

As we have discussed, the tourism sector depends on fossil fuel-based energy consumption to facilitate traveling and accommodation. Heavy reliance on this type of energy can contribute to CO₂ emissions, thus usage of renewable energy resources by the tourism sector can mitigate such emissions (Isik & Magdalena, 2017). The importance of tourism and its recognized impact on generating employment and income in various countries have stimulated work on analyzing its relationship with either non-renewable/renewable energy consumption or CO₂ emissions or both. However, the results are inconclusive. For instance, Liu, Lai, and Kuok (2012) find a bidirectional causal relationship between energy consumption and tourism development with regard to Taiwan. Similar results are reached by Tiwari, Ozturk, and Aruna (2013) for OECD countries; and Sekrafi and Sghaier (2018) in Tunisia.

Kuo, Liu, and Lai (2012) conclude that tourism receipts might increase energy consumption and CO₂ emissions in China. In contrast to this, Lee and Brahmairene (2013) find that tourism may decrease CO₂ emissions for a panel of European Union countries, and similar results are found by Katircioglu (2014) with regard to Singapore. Zaman, Khan, and Ahmad (2011) find a unidirectional causal relationship stemming from tourism to CO₂ emissions. Similar results are found by Zhang and Gao (2016) in eastern China and Raza, Sharif, Wong, and

Abd Karim (2017) in the USA. Additionally, Katiricioglu (2014) confirms the contribution of tourism development to both energy consumption and CO₂ emissions in Turkey. Dwyer, Forsyth, Spurr, and Hoque (2010) find that tourism contributes to greenhouse gas emissions in Australia. Also, León, Arana, and Hernández-Alemán (2014) find that although tourism development contributes to environmental degradation in both developed and less developed countries, its effect is less in less developed countries. Similar results are found by Solarin (2014), Robaina-Alves, Moutinho, and Costa (2016), Sharif, Afshan, and Nisha (2017), Zaman, Shahbaz, Loganathan, and Raza (2016) and Dogan, Seker, and Bulbul (2017). Moreover, Ozturk (2016) referring to a panel of 34 developed and developing countries finds that there is a positive relationship between CO₂ emissions and tourism indicators and a negative relationship between energy consumption and tourism indicators. As for Paramati, Shahbaz, and Alam (2017), they find that tourism decreases environmental degradation in western European Union countries while it increases it in eastern European Union countries. Also, mixed results are found by Isik, Doğan, and Ongan (2017) for the causality relationship between energy consumption and tourist arrivals and receipts for the top-most visited countries.

As mentioned above, renewable energy consumption is now a vital determinant that can mitigate environmental degradation, but there are a limited number of studies that are concerned with the relationship between tourism development and renewable energy consumption. This stream of literature is yet to reach any clear conclusions. Among these studies, Ben-Jebli, Ben-Youssef, and Apergis (2014) find that tourist arrivals and renewable energy consumption mitigate CO₂ emissions for Central and South America and they confirm the bidirectional causal relationship between tourist arrivals and environmental degradation. Isik, Dogru, and Turk (2017) conclude that there is a unidirectional causal relationship from tourist arrivals to

renewable energy consumption in Italy, Spain, Turkey and USA, and unidirectional causality from renewable energy consumption to tourist arrivals in China and no causality in France and Germany.

The above-mentioned studies use various methodologies including ARDL model, Johansen cointegration model, Generalized Method of Moments, panel cointegration, OLS, FMOLS, Pedroni and Kao panel co-integration techniques, wavelet transform framework, vector error correction model, etc. So far findings are mixed due to different methodologies used, variables used and time periods chosen. Moreover, the effect of renewable energy consumption on tourism development is not clear as there are very few studies that investigate this relationship.

3. Data and methodology

3.1. Model

This study aims to assess the association between tourism, renewable and fossil fuel energy consumption, and CO₂ emissions in China following the frequency domain analysis. While analysing this association, we are interested in understanding the nature of co-movement among these variables, and not their long run coefficients. In doing so, we need to confirm their long run cointegrating association in the time domain, as the tests confirming this association are the diagnostic tests for assessing the co-movement among these variables. The question of including other variables might arise in this pursuit, and we need to explain the reason for not considering other variables. In keeping with the objective of this study, we need to assess the association of these variables through co-movement, and not through assessing long run coefficients. Hence, adding additional explanatory variables will not have any effect on the estimation results.

Therefore, this estimation processes have considered only four variables: tourism, renewable and fossil fuel energy consumption, and CO₂ emissions.

In keeping with the research objective, we hypothesize that there is a possible co-movement between tourism, renewable energy consumption, fossil fuel energy consumption, and CO₂ emissions for China in the frequency domain.

3.2. Data

The main variables include tourist arrivals (TOR), renewable energy consumption (RENEW), energy consumption (ENC) and CO₂ emissions (CO₂) and all variables are in annual frequency ranging from 1974-2017. TOR is measured by the number of tourist arrivals per year in the country during the study period. Renewable energy consumption is measured in kilotons and energy consumption is calculated as the sum of total primary energy used. It is measured in kilogram oil equivalent. Finally, CO₂ as a proxy for environmental degradation is calculated as the total emission of carbon dioxide and is measured in kilotons. The data for all the variables except renewable energy, are obtained from the World Bank (World development indicator). Renewable energy data is collected from National Bureau of Statistics, China. It is converted into natural logarithm of difference series in order to acquire the return-series to make our conclusion more comparable. The time period is selected by the availability of data and to assure that data for all the variables under study is complete for the period 1974-2016. Aloui, Hkiri, Hammoudeh, and Shahbaz (2018) conducted a similar analysis with annual data from 1969-2014 for the oil price, inflation, exchange rate, and economic growth nexus in Saudi Arabia.

3.3. Methodology

We employed different methods of wavelet in order to examine the linkage among tourism, energy consumption, renewable energy consumption and carbon dioxide emission. This is explained essentially by the ability of these methods to focus and follow the varying outlines of time scale. In fact,

the technique of wavelet allows the prediction of time series' spectral features as being a time function and also an explanation of the variation over time of time series' periodic components. Particularly, we can use continuous wavelets, coherence of wavelet, multiple wavelet coherence and wavelet power between various approaches of wavelet technique. In addition, Ruan and Nunes (2009) argued that the technique of cross wavelets has the ability to decompose in the first time and reconstruct in the second time the following function:

$$x(t) = 1/C_{\psi} \int_0^{\infty} [\int_{-\infty}^{\infty} Wx(u, s) \psi_{u,s}(t) du] ds/s^2, s > 0 \quad (1)$$

The efficiency of the approach of wavelet coherence is due to its measure of the coefficient across series of localized correlation especially in the domain of time-frequency. By the way, the wavelet method coherence is measured through dividing the smoothed CWS' absolute value by the WPS of smoothed individual product for each series.

$$R^2(u, s) = \frac{|S(s-1Wxy(u,s))|^2}{(S(s-1Wx(u,s))^2 S(s-1Wy(u,s))^2)} \quad (2)$$

After employing both techniques such as wavelet coherence and cross-wavelet, we may apply for the methods of multiple and partial wavelet. Particularly, these two methods contribute in the inclusion of control variables in a multivariate framework. However, this is not possible via both coherency approaches of wavelet and wavelet coherence. We can thus detect the impact of control variables on carbon dioxide emission. Moreover, in the framework of a bivariate wavelet and in order to avoid series 'comparison, we use the methods of partial and multiple wavelet coherency. Some authors suggested that these methods eliminate the bias of oscillations' low frequency, which exists frequently in the prediction of power spectrum of wavelet approach (Liu, Liang, & Weisberg, 2007; Veleda, Montagne, & Araujo, 2012). We should note that the techniques of a multivariate wavelet add a new variable which is considered a third variable and also a conditioning factor.

Besides, the difference between partial and multiple wavelet coherence methods is that the partial investigates the two variables' influences on a third one, but the second wavelet method is considered more akin to a various association, which is thus applied for testing the impact of many independent variables on a single one.

The following expression presents the approach of the specific method of partial wavelet coherence. It allows the identification of the wavelet coherence (WC) among both series (y , x_1) after deleting the third series (x_2) impacts. The expression of the current function is showed as follows:

$$RP^2(y, x_1, x_2) = \frac{|R(y, x_1) - R(y, x_2) \cdot R(y, x_1)|^2}{[1 - R(y, x_2)]^2 [1 - R(x_2, x_1)]^2} \quad (3)$$

By using PWC technique, we may employ multiple wavelet coherency approach. The latter is identical to the multiple associations. In fact, in order to predict the coherence of many variables on a dependent one variable, we use the MWC, which has the power to examine this linkage. The model function of multivariate wavelet coherence is presented as follows:

$$RM^2(y, x_2, x_1) = \frac{R^2(y, x_1) + R^2(y, x_2) - 2Re[R(y, x_1) \cdot R(y, x_2)^* \cdot R(x_1, x_2)^*]}{1 - R^2(x_1, x_2)} \quad (4)$$

4. Empirical results

This section discusses the data analysis focusing on the dynamic relationship between tourism, energy consumption, renewable energy consumption and CO₂ emissions evidence from China.

4.1. Unit Root test and Long-run Cointegration

The main objective of this study is to investigate the relationship between tourism, renewable energy consumption, energy consumption and CO₂ emission in China. Before applying the statistical analysis, the time series of our variables are transformed into natural logarithms. The

reason behind the transformation of natural series into logarithms is because we are assuming the information that results are more efficient in returns rather than actual value (Tiwari, Bhanja, Dar, & Islam, 2015). Fig. 1, plots the actual as well as log-transformed difference time series data for all the variables under study. It can be observed that the actual series appears to be non-stationary, whereas converted first difference of all the series seems to be stationary. Moreover, all the actual series demonstrates rising trends.

<Insert Figure 1 here>

Conversely, substantial fluctuations can be seen in the real difference series indicating that there exist significant changes in all the variables under the study and for the entire study period. The descriptive statistics and correlation matrix for the variables are shown in Table 1. The CO₂ emission and renewable energy consumption show the highest and the lowest standard deviation, respectively. All the series have accepted the Jarque-Bera test and confirm that they are not normally distributed, which is common for most of the time series data (Shahzad, et al., 2017). Furthermore, the correlation matrix shows significant relationships between the variables.

<Insert Table 1 here>

Next, the autoregressive distributed lag method for cointegration is used to estimate the long run relationship between tourism, renewable energy consumption, energy consumption and CO₂ emission. Table 3 shows the results of ARDL cointegration method.

<Insert Table 2 here>

The ARDL results reject the null hypothesis of no cointegration against the alternative hypothesis that a valid long-run relationship exists between tourism, renewable energy consumption, and CO₂ emission in China as the value of the *F*-statistics is greater than the upper bound critical value at 1 percent level of significance.

<Insert Table 3 here>

The Johansen and Juselius (1990) cointegration method is used to estimate the long run relationship. Table 4 represents the calculated and critical values of Trace statistics and Maximum Eigenvalue statistics of the Johansen and Juselius (1990) cointegration method. The results indicate the rejection of the null hypothesis of no cointegration in the model at a significance level of 5 percent in favor of the alternative hypothesis that there exists one or more cointegrating vectors. The findings confirm the existence of long-run relationship between tourism, renewable energy consumption, energy consumption and CO₂ emission in China.

4.2. Continuous Wavelet Transform

Continuous wavelet power spectrum results for TOR, RENEW, ENC and CO₂ emission for China are displayed in Fig. 2. The horizontal axis measures the time period depicting five-years in progression from 1974-2016. The Y-axis measures the periodic cycle say 0-4, 4-8 etc. The direction of Y-axis is in reverse scale, i.e., closer to the Y-axis represents more long term scale. It can be seen that in the case of TOR, there are patterns of strong variance in small-medium runs. As for RENEW and ENC, the high variance is visible in small scales, but not in medium and long runs, while CO₂ emission has a strong variance in the long run (lower panel, right, Fig. 2). TOR mostly exists in small time scales during 1981-1985 and also for medium scales in between 1985-1990. However, for the entire study period, high-scale variance seems to be almost non-existent. Alternatively, inbound tourism is a bit volatile in the short-medium run, but the stability remains in the long-run. In the cases of RENEW and ENC, a strong variance exists in periods 0-4 yearly cycles during 2010-2015. As for CO₂ emission, a strong variance can be seen in the long-run during 1985-2005. These outcomes suggest that TOR, RENEW, ENC show more variance in the medium-run, but CO₂ emission has a significant variance in the medium-

long run. Also, the common islands between the two series exist during 1980-1985 for TOR and CO₂ emission and later 2010-2015 for RENEW and ENC (Fig. 2). The relationship between the described patterns in the bivariate relationship using continuous wavelet transform (Fig. 2) is not very clear and comprehensible. Moreover, the connections between the patterns are low, hence, further investigation is performed using wavelet coherence.

<Insert Figure 2 here>

4.3. Wavelet Coherence

The results of the bivariate relationship between the variables using wavelet coherence are presented in Fig. 3. The wavelet transform coherence locates the sections in time-frequency space in which two time series co-vary. Fig. 3 provides some interesting findings. The results of wavelet coherence for TOR-RENEW shows that in the period of 0-4 years cycle during 2012 onwards, the arrows are right-side-up explaining that the variables are in-phase showing cyclic effect with RENEW as leading variable suggesting that renewable energy consumption can predict the number of international tourists flowing into the country. **Renewable energy consumption (RENEW) is the leading variable in this co-movement, and thereby, it can act as a movement predictor for the TOR, which is the tourist arrivals.** The result for TOR with ENC and CO₂ (upper panel) emission is quite similar, revealing that in the period of 4-8 years cycle during 1985-1990, the arrows are left-side-up suggesting that the variables are out-phase and indicating an anti-cyclic effect with ENC and CO₂ lagging. It indicates that ENC and CO₂ emission tend to have delayed reactions to a change in international tourist flows. The RENEW-ENC results are that in the period of 0-4 cycle during 2000-2007, the arrows are left-side-up indicating that ENC-RENEW is out-phase showing anti-cyclic effect with ENC lagging. Moreover, the results of RENEW-CO₂ emission suggest that in the period of 0-4 year cycle during 2009-2013, the arrows

are left-side-down explaining that the variables are out-phase and showing anti-cyclic effect with CO₂ is lagging. Alternatively, the level of CO₂ emission depends on the changes in the renewable energy consumption. Finally, the result of ENC-CO₂ emission shows that 4-16 years cycle during 1985-2015, the arrows are mostly right-side-up explaining that ENC-CO₂ emission is in-phase displaying a cyclic effect with CO₂ emission leading, which indicates that fossil fuel energy consumption can predict the future changes in the level of CO₂ emission. Overall, the results of wavelet coherence reveal that tourism is influenced by renewable energy consumption. Moreover, renewable energy consumption can lower carbon emission and increase international tourist flows in the short-medium run for sustainable development in China. Conversely, tourism can influence ENC and CO₂ in China.

<Insert Figure 3 here>

4.4. Partial Wavelet Coherence

This subsection presents the results of partial and multiple wavelet coherence where, PWC is the partial wavelet coherence result (left-panel, Fig. 4), and MWC explains the multiple wavelet coherence plots (right-panel) between tourism, energy consumption, renewable energy consumption and CO₂ emission in China. Fig. 4a reports the partial wavelet coherence between energy consumption and renewable energy consumption after canceling out the CO₂ emission. The correlation is found to be weak and only one red color significant island is identified during 2011-2013, for 4-8 years cycle (medium-run horizon). However, when considering CO₂ emission in the ENC-RENEW relationship (Fig. 4b), a comparatively different condition is observed. A strong co-movement is noticed for both medium and high-frequency bands during the entire sample period. Predominantly, in the short-run, one island from 0-4 years cycle, where the correlation ranges from 0.9-1.0 (strong correlation) is noticed. In the medium-long run, the

presence of one island in whole 4-8- and 8-16-year cycles is identified, with the correlation ranging from 0.8-1.0. Overall, the partial and multiple wavelet coherence specify a robust effect of CO₂ emission in examining the relationship between RENEW and ENC in China. The results are also consistent with the pair-wise Granger causality test, verifying the existence of causality running from ENC to RENEW and from RENEW to CO₂ emission.

<Insert Figure 4 here>

Fig. 4c shows the partial wavelet coherence between energy consumption and renewable energy after canceling out the tourism effect. The correlation is found to be weak and only one yellow color significant island is identified in the 0-4 years cycle (short-run horizon) during 2002-2004. But, when considering tourism in the relationship between ENC and RENEW (Fig. 4d), a strong co-movement in short-medium period is noticed. In the 0-4 year cycle, we found the presence of three islands during 1987-1991, 1997-2005 and 2011-2013 time period, where the correlation ranges between 0.7- 0.9. However, in the medium-run, there is a strong co-movement between ENC, RENEW and TOR. In the 4-8 year cycle, one strong red island is found during 1982-1986 with the correlation ranging from 0.7-0.8. The results are also consistent with the pair-wise Granger causality test, signifying the existence of causality running from ENC to RENEW and from RENEW to TOR in China. The results are consistent with the results of wavelet coherence that renewable energy influences inbound tourism in the short-medium run, but there is no effect in the long-run.

Figs. 4e and 4g illustrate the partial wavelet coherence between RENEW and CO₂ emission canceling out ENC and TOR, respectively. The correlation is found to be weak and only one small red color significant island is identified in a 0-4 years cycle during 2008-2010 (cancelling out ENC) and 2006-2009 (cancelling out TOR). However, when considering ENC

and TOR, in the relationship between RENEW and CO₂ emission (Figs. 4f and 4h), a strong co-movement is observed in the short-medium run of RENEW, CO₂ emission and ENC. In the 0-4- and 4-8-year cycles, we found the existence of two red islands during 1989-1991 and 2003-2011, where the value of correlation ranges between 0.7-0.9. In Fig. 4h, from the 0-4- and 4-8-year cycles, we found the presence of three red islands during 1986-1991 and 2006-2012 in the short-run and from 1981-1986 in the medium-run, where the value of correlation ranges between 0.7-0.9. The results confirm the earlier findings (wavelet coherence) that tourism affects renewable energy consumption and carbon emissions in the short and medium run. The emergence of electric vehicles and vehicles run by clean energy sources are being implemented by the policymakers in various tourism destinations in China, and this move might increase the demand for renewable energy and decrease the level of CO₂ emissions in the short run. This segment of the results might not hold true for the long run, as the gradual rise in tourist arrivals in these destinations might gradually increase the level of CO₂ emissions through rise in the tourism-allied industrial activities and tourism related activities. In order to enhance the attractiveness of these destinations, these tourism-allied industrial sectors will be boosted through fossil fuel energy consumption. In such a scenario, long run association can be established through the intervention of tourism investment in pursuit of augmenting renewable energy consumption.

Figs. 4i and 4k show the partial wavelet coherence between TOR and CO₂ emission canceling out ENC and RENEW, respectively. The correlation is found to be weak and only one small red color significant island is identified for the 4-8-year cycle during 1981-1987 (cancelling out RENEW), whereas no relationship is found between TOR and CO₂ emission (cancelling ENC). The results suggest that tourism and CO₂ emission are correlated. However, when considering ENC and RENEW, in the relationship between TOR and CO₂ emission (Fig.

4j and 4l), a solid co-movement in the short-medium run is detected for RENEW, CO₂ emission, and TOR. In the 0-4- and 4-8-year cycle, we found the existence of three red islands during 1987-1993 and 1997- 2001 in the short-horizon and during 1980-1986 in the medium-horizon, where the value of correlation ranges between 0.7-0.8. In Fig. 4l, from the 0-4- and 4-8-year cycle, we found the presence of two red islands during 1988-1990 in the short-run and from 1981-1989 in the medium-run, where the value of correlation ranges between 0.7-0.8. It is evident that energy consumption and renewable energy consumption influence the correlation between TOR and CO₂ emission.

Figs. 4m and 4o display the PWC between ENC and CO₂ emission canceling out TOR and RENEW, respectively. The correlation is found to be very strong and a one large red color significant island is identified for 4-8- and 8-16-year cycle during the whole period (cancelling out RENEW and TOR individually) illustrating the general concerns that ENC and CO₂ emission are highly correlated. While considering TOR and RENEW, in the relationship between ENC and CO₂ emission (Fig. 4n and 4p), we identified a firm co-movement in short-medium-long run of RENEW, CO₂ emission, and TOR. In the 0-4 year cycle, we found the existence of one red island during 1986-1991 and in the 4-8 and 8-16 year cycle, we find one large red island for an entire period where the value of correlation ranges between 0.8 to 0.9. In Fig. 4p, from the 0-4 year cycle, we found the presence of two red islands during 1988-1991 and 1996-2001 in the short-run. In the 4-8 and 8-16 period, again we see one large red island for an entire period where the value of correlation ranges from 0.8-0.9. In other words, tourism and renewable energy consumption do affect the correlation between energy consumption and CO₂ emission.

Figs. 4q and 4s explain the partial wavelet coherence between the sets: changes in TOR and ENC excluding RENEW and CO₂ emission. The strong co-movement is located at the 4-8-

year cycle during 1981-1985 in a medium-run (cancelling out RENEW), whereas, a weak co-movement is presented in the 0-4 year cycle during 1998-1999 (cancelling out CO₂ emission). There is not much correlation between TOR and ENC, if RENEW and CO₂ are excluded. When focusing on TOR and ENC in the relationship between RENEW and CO₂ emission (Figs. 4r and 4t), we identify a strong co-movement in the short-medium year cycle where the value of the correlation ranges from 0.8-0.9 suggesting that RENEW and CO₂ influence the relationship between TOR and ENC. Fig (4u) and (4w) display the PWC between TOR and RENEW canceling out CO₂ emission and ENC, respectively. The correlation is found to be very strong and only one small red color significant island is identified during 1982-1987 (cancelling out CO₂ emission and ENC individually) for the 4-8-year cycle (long run). The results confirm that TOR and RENEW are correlated in the medium-run with the influences of CO₂ and ENC. While considering CO₂ emission and ENC, in the relationship between RENEW and TOR (Fig. 4v and 4x), we identify a firm co-movement in short-medium run of RENEW, CO₂ emission, and TOR. In the 0-4-year cycle, we found the existence of one red island during 1986-1991 and in the 4-8 year cycle, one large red island for 1981-1989 period is seen where the value of correlation ranges from 0.8-0.9. In Fig. 4x, from the 0-4-year cycle, we found the presence of two red islands during 1986-1992 and 2011-2012 in the short-run. In 4-8 cycle, again one large red island for 1980-1988 period is seen, where the value of correlation ranges from 0.8-0.9. So, CO₂ and ENC affect the TOR-RENEW relationship. Overall, the findings confirm that tourism is correlated with renewable energy and CO₂ emission especially in the short-medium run, but the correlation disappears in the long-run. However, CO₂ emission affects fossil fuel energy as well as renewable energy consumption in the long-run. As China is gradually moving towards the business of ecotourism, therefore it is important for the policymakers to retain and improve the

environmental quality of the tourism destinations. Henceforth, the policymakers might try to implement renewable energy solutions by gradually replacing the fossil fuel energy solutions, as the latter is responsible for rise in CO₂ emissions in the ambient atmosphere. So, the rise in the CO₂ emissions compelled the policymakers to increase renewable energy consumption and reduce fossil fuel energy consumption.

5. Conclusion

By far, we have evaluated the associative co-movement between tourism, renewable and fossil fuel energy consumption, and CO₂ emission in China, by means of wavelet transform and wavelet coherence methods. The contribution of this study is in terms of divulging the way, in which the associative movement between sustainable tourism and ecological sustainability in China changes its course along the frequency domains. For temporal domain, our results demonstrate heterogeneous association among the model parameters, whereas in frequency domain, the associations are both coherent and the model parameters are having lead-lag associations. The phase-wise outcomes show that these associative movements vary along the temporal domain for medium and short runs. Lastly, the results confirm the presence of significant association between the model parameters in the frequency domain through their lead-lag associations.

Also, the findings suggest that energy consumption and CO₂ emission act as lagging indicators for tourism. In other words, international tourism increases the energy consumption and CO₂ emissions. Given that China has experienced an estimated 288% increase in international tourist numbers over the 15-year period from 1995-2009 (Gössling et al., 2013), it is highly plausible that this tourism growth has not been environmentally sustainable. International tourism involves such a movement of people over long distances, as well as their

accommodation and activities, the direct contribution to greenhouse gases is clearly going to be quite substantial.

So, the question arises: can China's tourist growth continue while, in overall terms, the emissions of CO₂ associated with China decline? Here, our results are supportive of this outcome being possible. That is, our findings suggest that tourism and consumption of renewable energy facilitate reduced CO₂ emissions in the short-medium run in China. Renewable energy acts as a leading indicator implying that converting energy consumption to renewable energy further enhances the international tourist flows and promotes sustainable tourism by lowering CO₂ emission. This suggests that policy makers should make contingency plans for generating renewable energy to deal with the threat of global warming in the next two-to-three years and to promote tourism with an emphasis on sustainability.

As mentioned earlier, energy consumption in tourism, to a large extent, comes from transportation activities involving long distance air and sea travelling, hence, promoting a sectoral shift from long distance international tourism to domestic and regional tourism can moderate CO₂ emission and hence global warming. Moreover, construction of accommodation including multi-storied buildings is an energy intensive activity (Rossello-Batle, Moia, Cladera, & Martinez (2010) point out the importance of recycling construction materials to counteract global warming). The adoption of clean technologies using renewable energy for production purposes and promoting eco-tourism for its sustainability has the potential to achieve the objectives of developing the tourist industry and reducing CO₂ emission.

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Table 1. Descriptive statistics

	TOR	RENEW	ENC	CO2
Mean	6759.656	211489.900	1112.545	4530932.000
Maximum	15053.940	306458.300	2236.730	10291927.000
Minimum	168.234	174584.900	537.175	1196194.000
Std. Dev.	5129.251	24102.240	555.444	3158145.000
Skewness	0.184	0.722	0.842	0.826
Kurtosis	1.451	1.828	2.154	2.159
Jarque-Bera	24.436	61.562	6.214	6.008
Probability	0.000	0.000	0.045	0.050
Correlation Matrix				
TOR	1			
RENEW	0.619* (0.000)	1		
ENC	0.926* (0.000)	-0.555* (0.000)	1	
CO2	0.931* (0.000)	-0.632* (0.000)	0.992* (0.000)	1

Note: * denotes the rejection of the null hypothesis at the 1% significance level

Table 2: Lag Length Selection & Bound Testing for Cointegration

Lags Order	AIC	HQ	SBC	F-test Statistics
0	-3.258	-3.796	-3.689	
1	-12.209	-12.304	-12.165	59.456*
2	-12.05	-11.998	-11.427	

Note: * denotes 1% level of significance.

Source: Authors' estimation.

Table 3: J. J. Cointegration Test

Null Hypothesis No. of CS(s)	Trace Statistics	5% critical values	Max. Eigen Value Statistics	5% critical values
None *	63.227	59.061	33.171	30.961
At most 1	34.056	38.175	19.253	21.159
At most 2	15.804	20.276	9.246	14.797

Note: * denotes 1% level of significance.

Source: Authors' estimation.

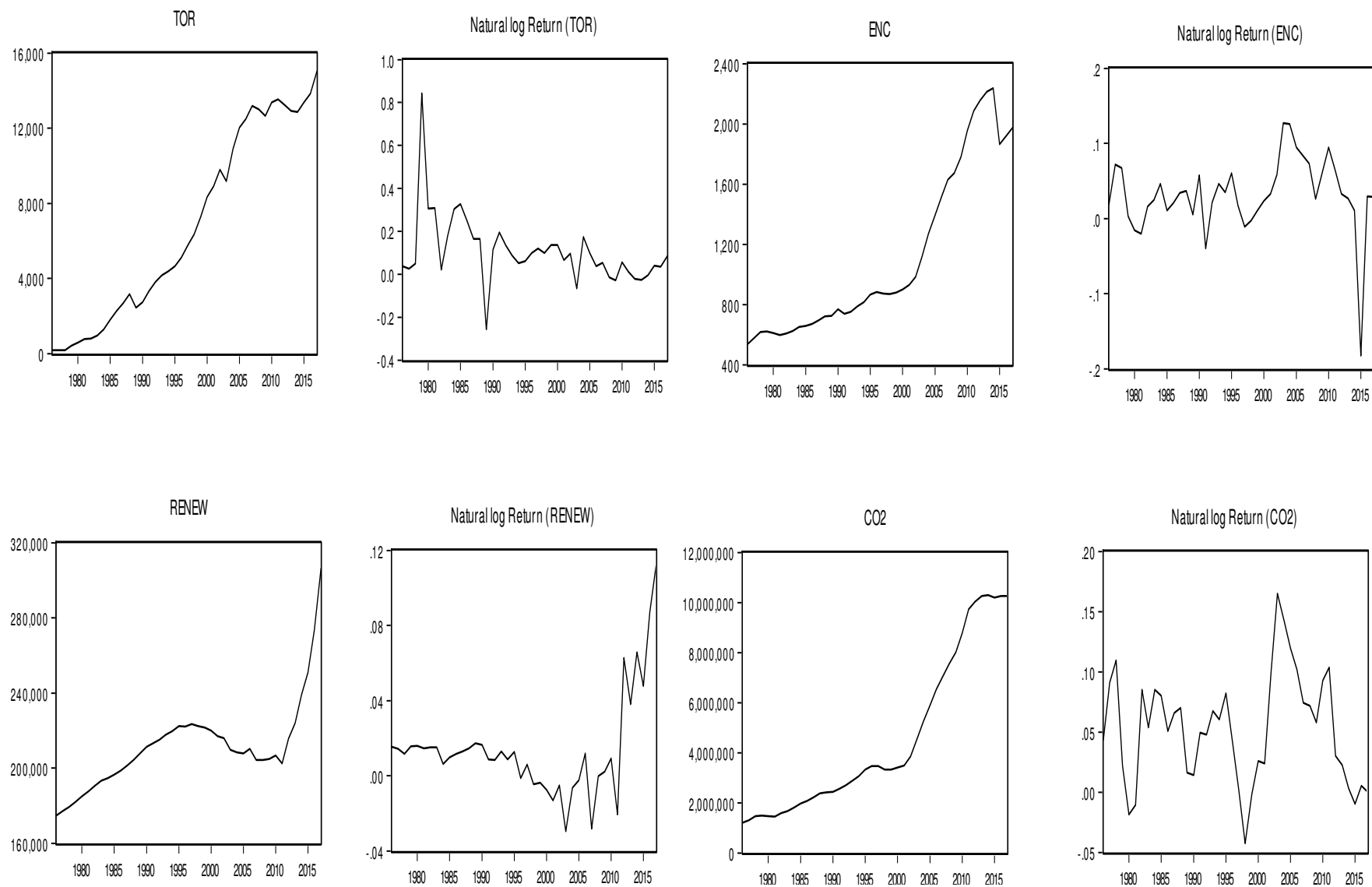
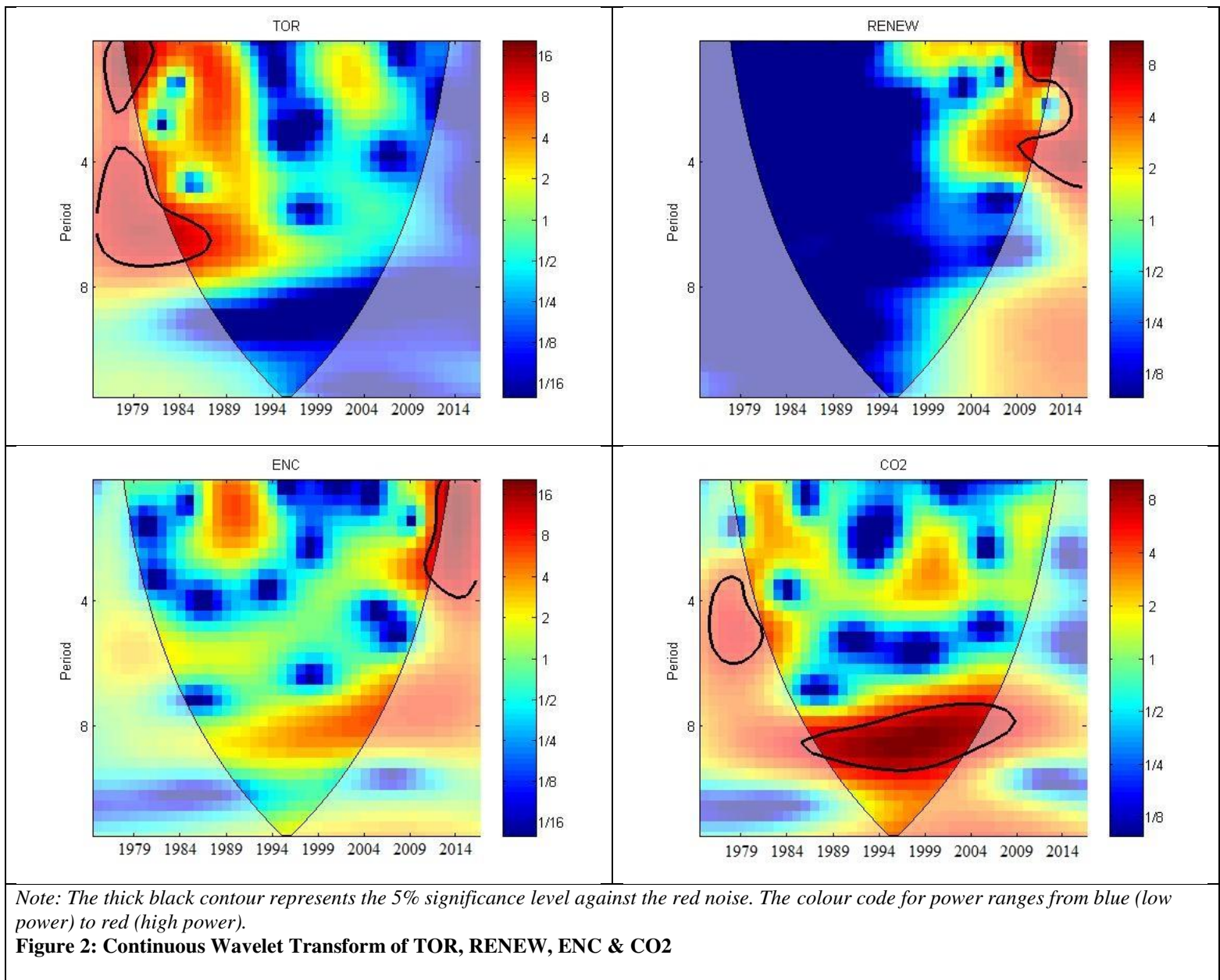
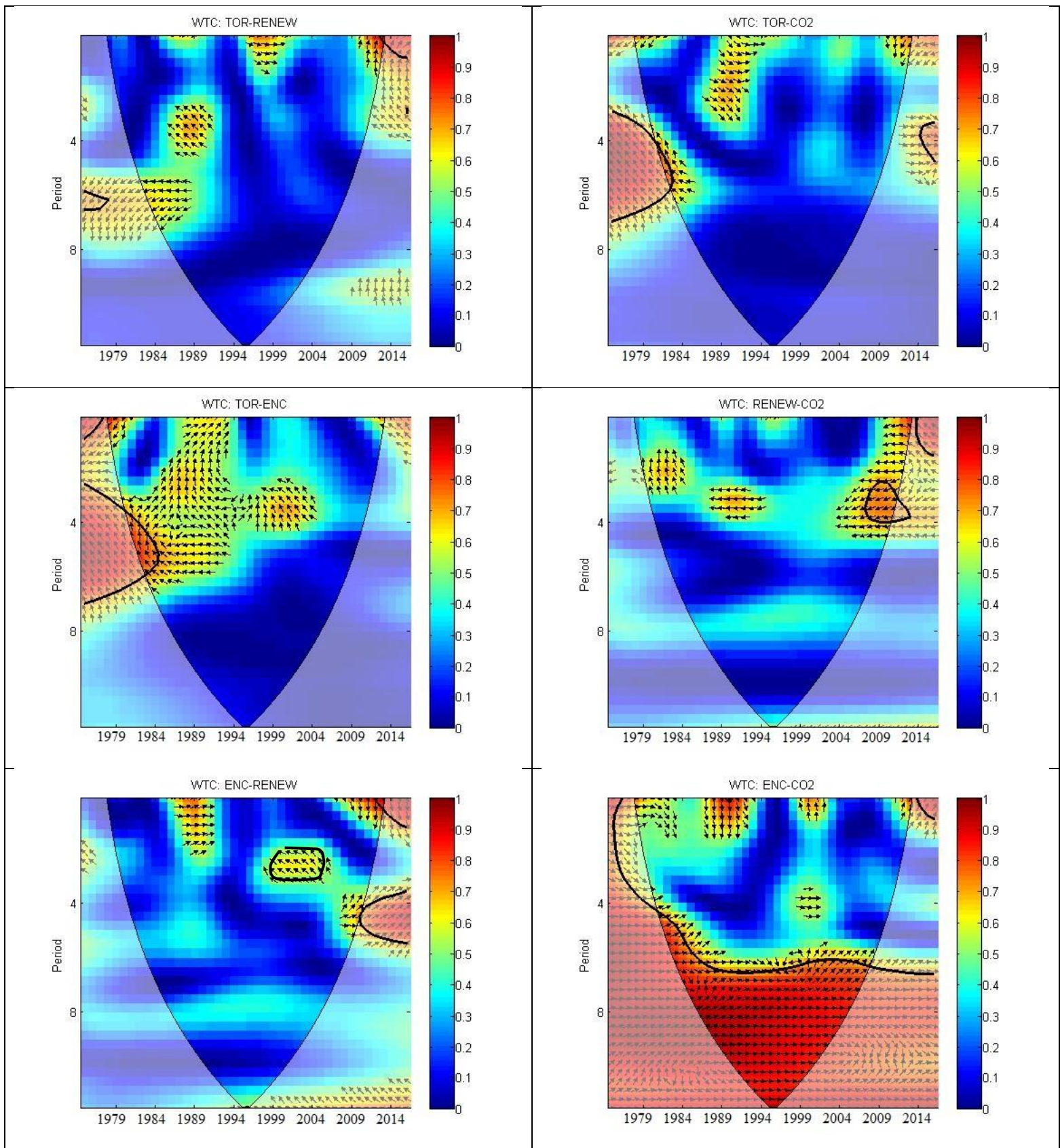


Figure 1: Actual and Natural log return series of TOR, ENC, RENEW & CO2

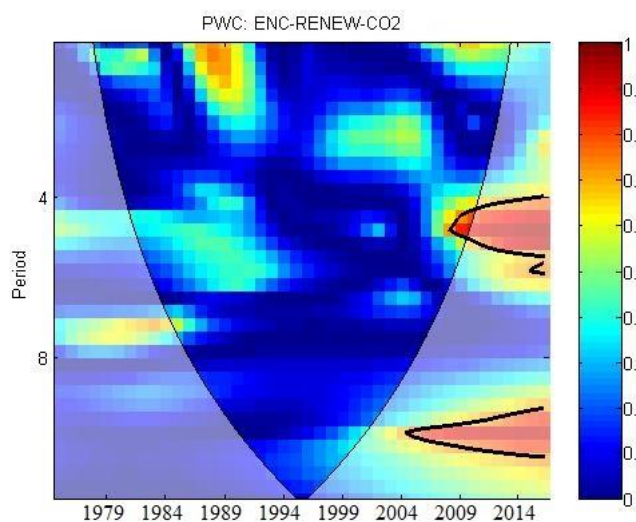




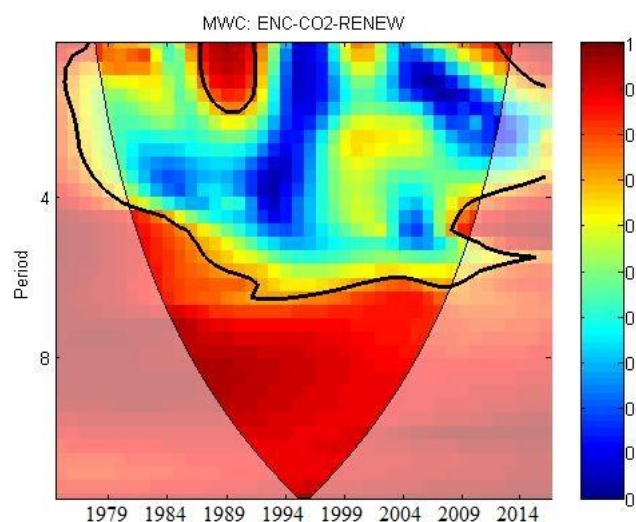
Note: The thick black contour represents the 5% significance level against the red noise. The colour code for power ranges from blue (low power) to red (high power).

Figure 3: Continuous Wavelet Transform of TOR, RENEW, ENC & CO2

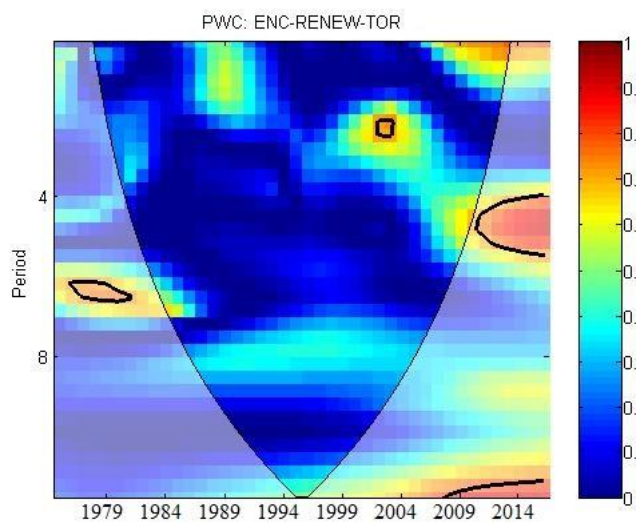
4(a)



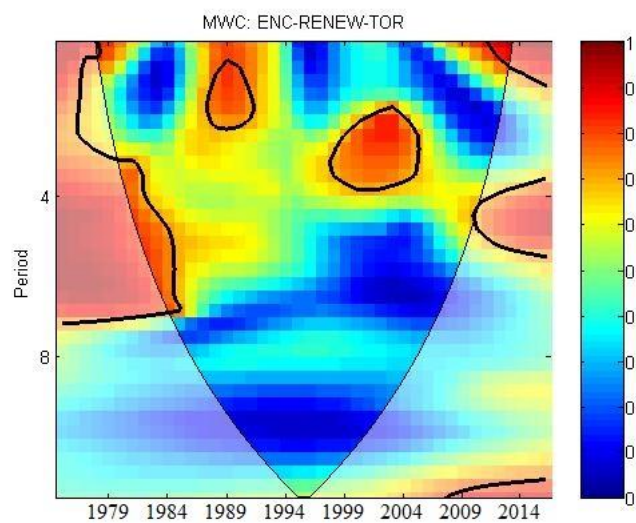
4(b)



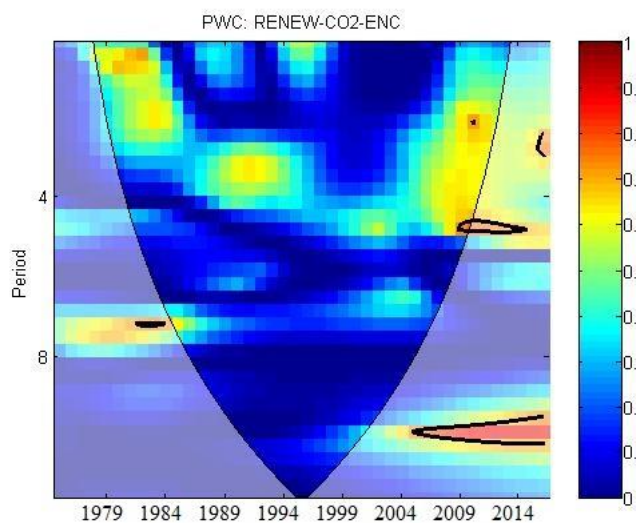
4(c)



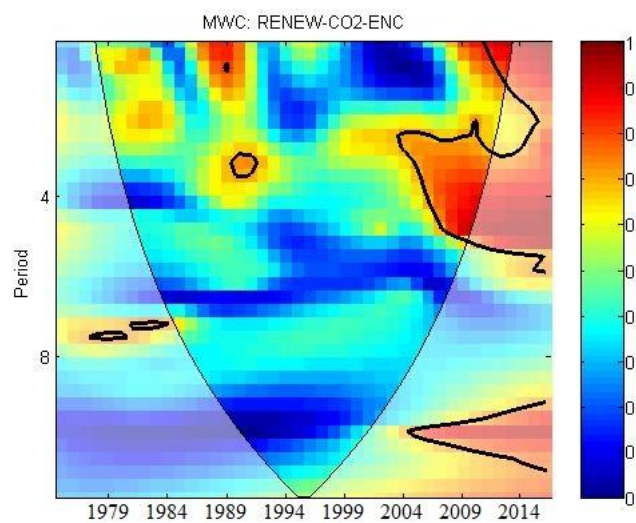
4(d)



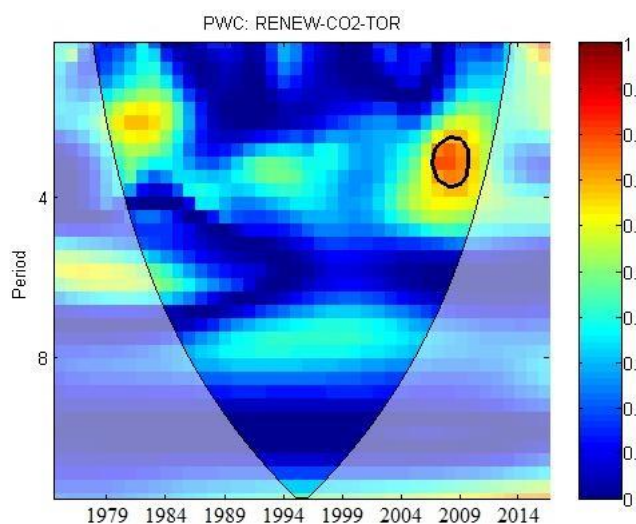
4(e)



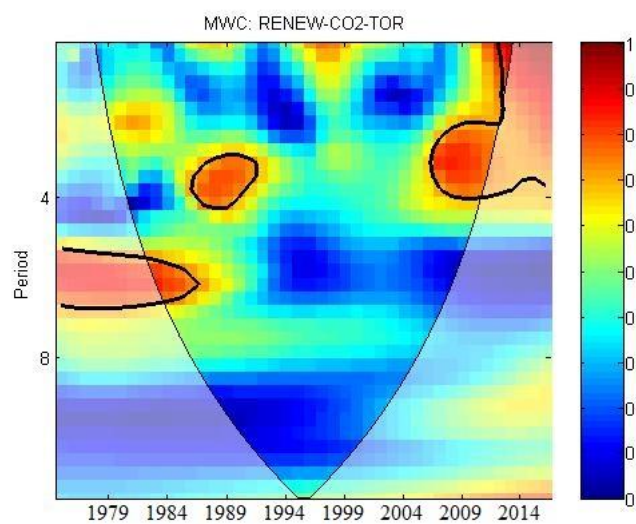
4(f)



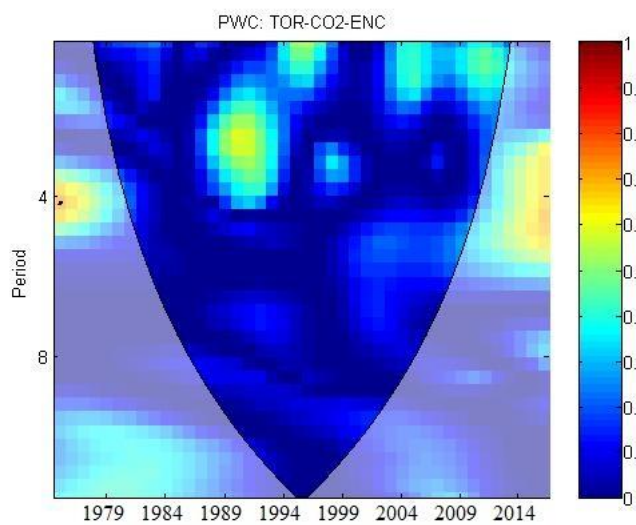
4(g)



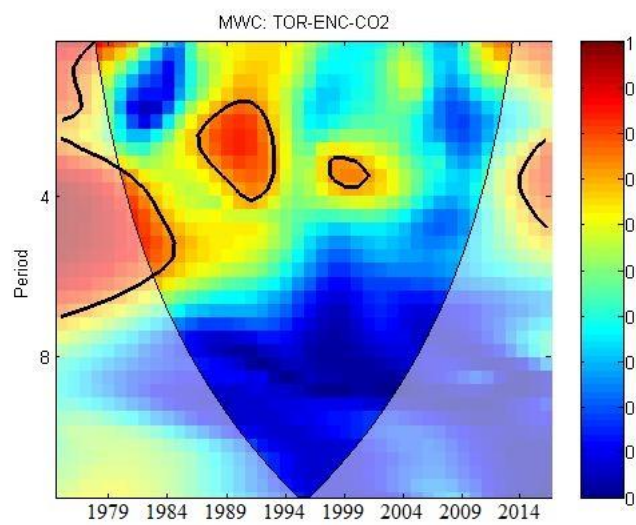
4(h)



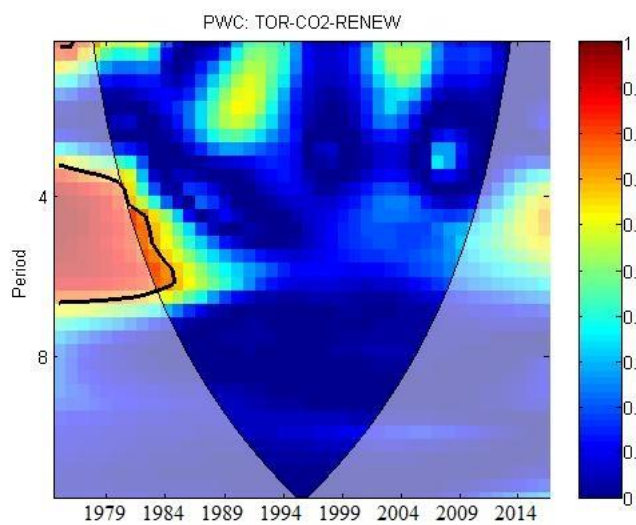
4(i)



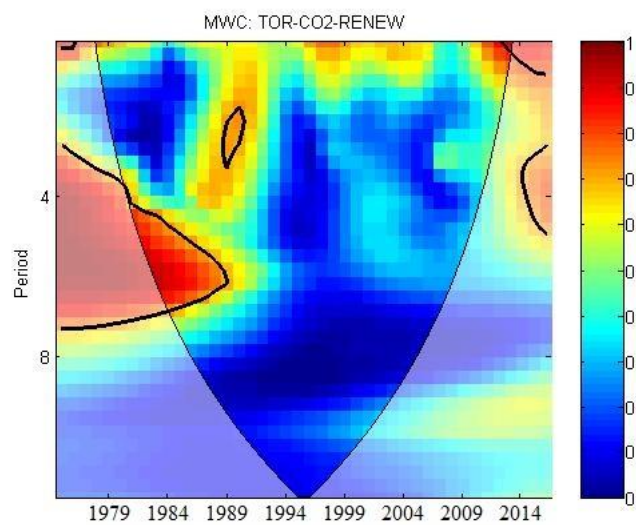
4(j)



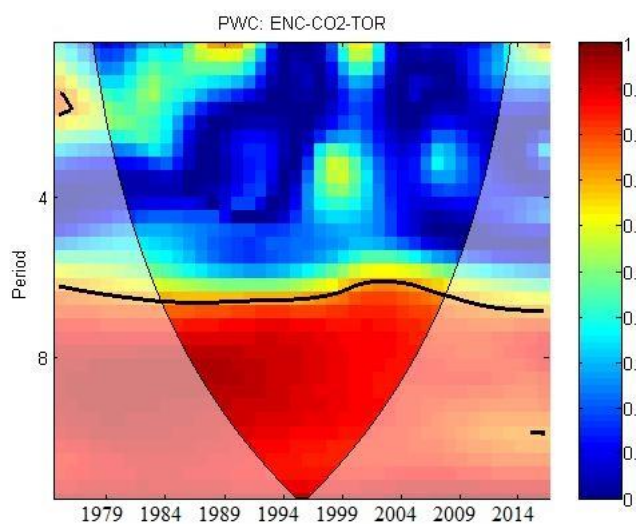
4(k)



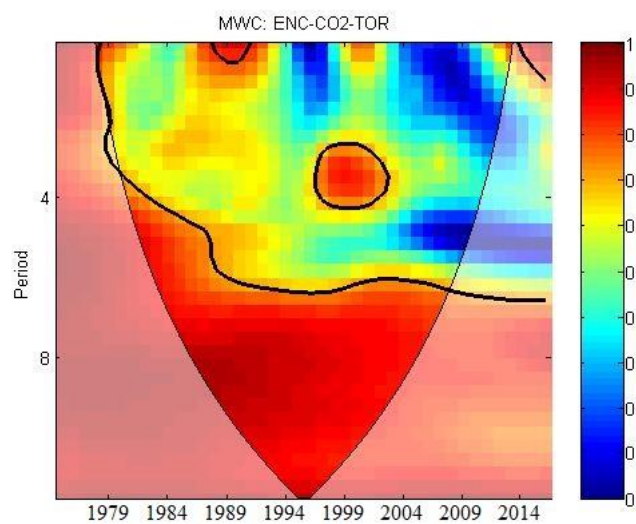
4(l)



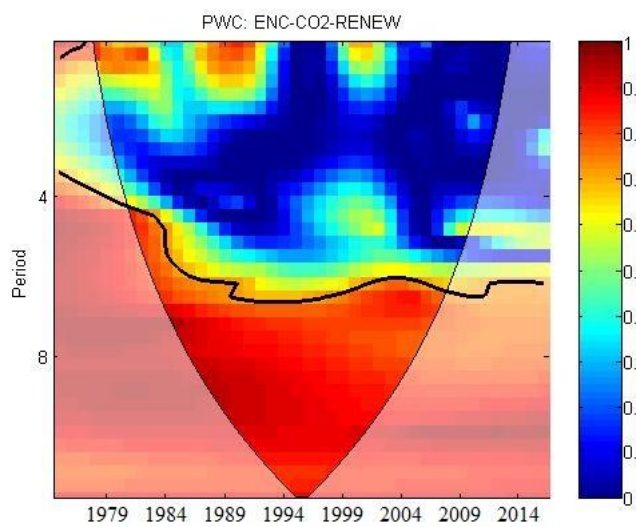
4(m)



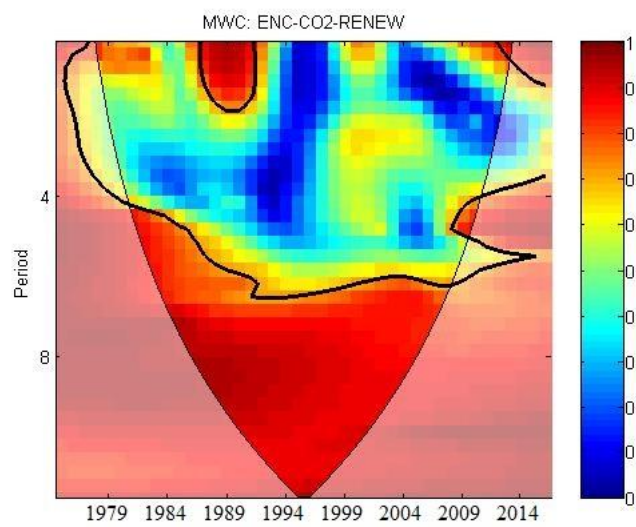
4(n)



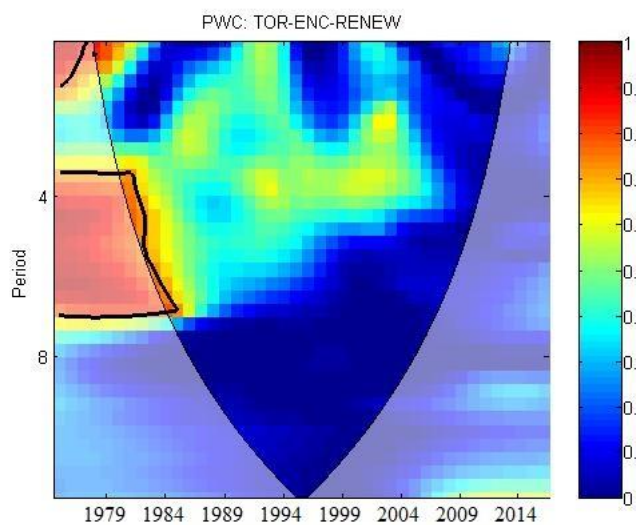
4(o)



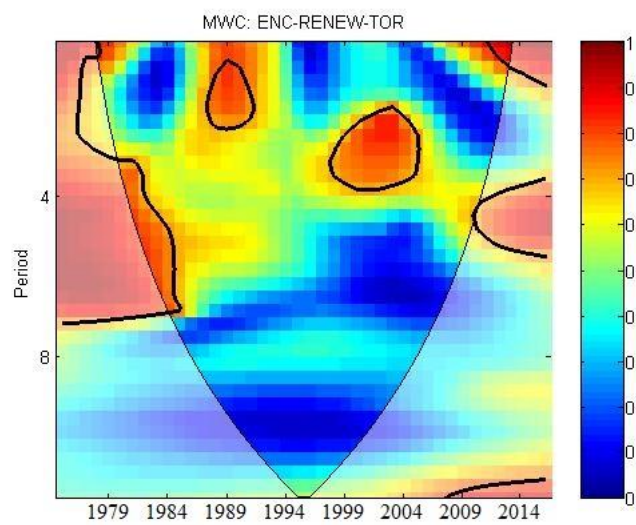
4(p)



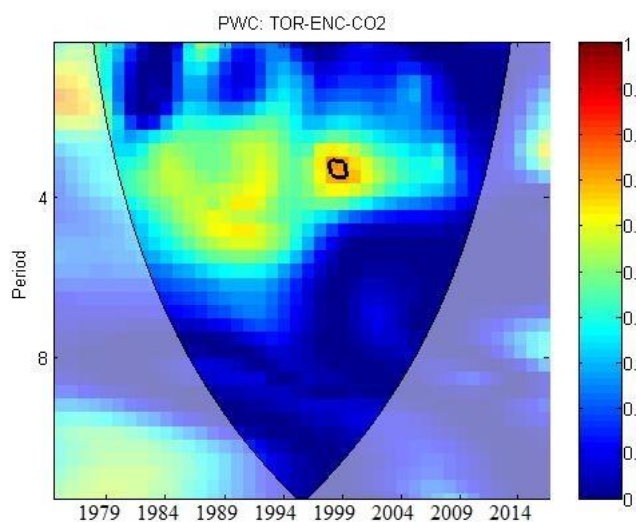
4(q)



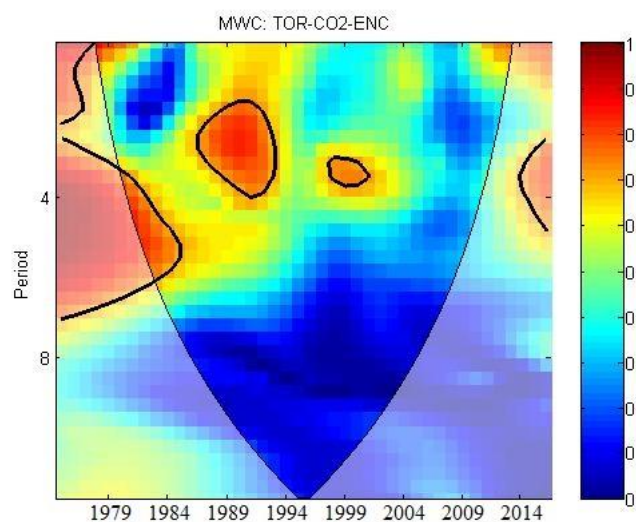
4(r)



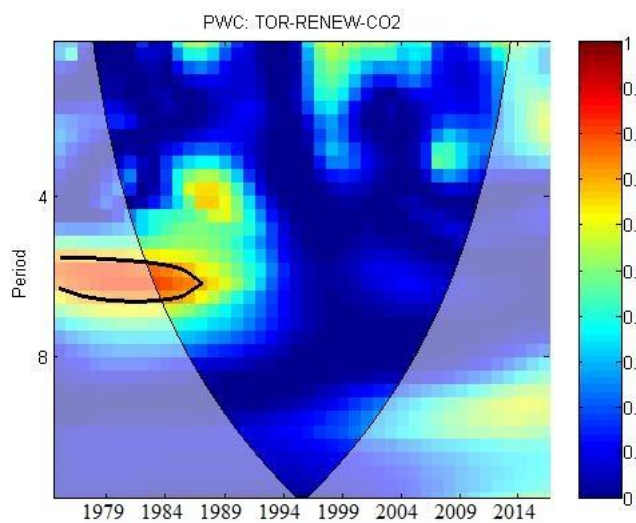
4(s)



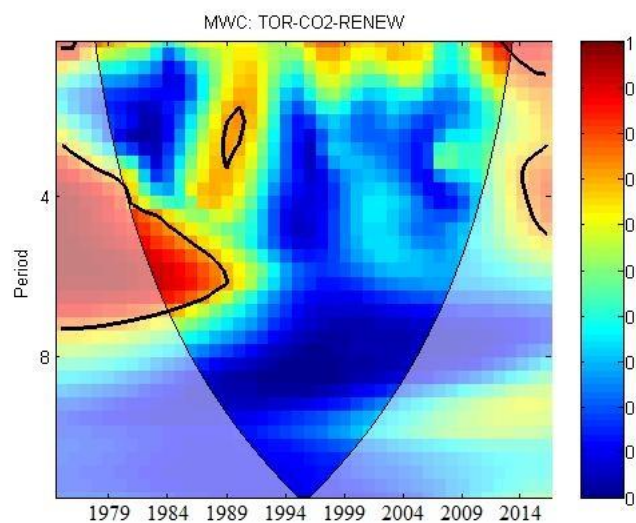
4(t)



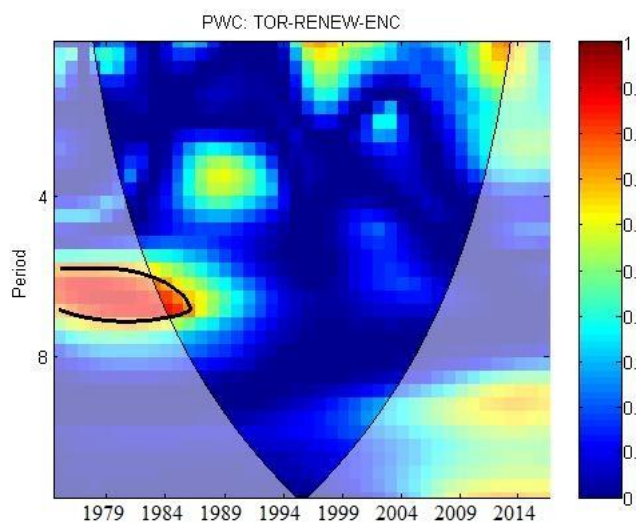
4(u)



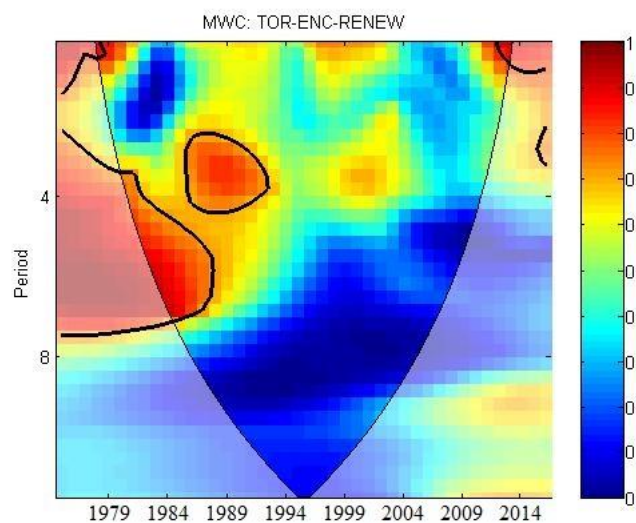
4(v)



4(w)



4(x)



Note: See Figure-3

Figure 4: Partial and Multiple Wavelet Coherences of TOR, RENEW, ENC, CO2

